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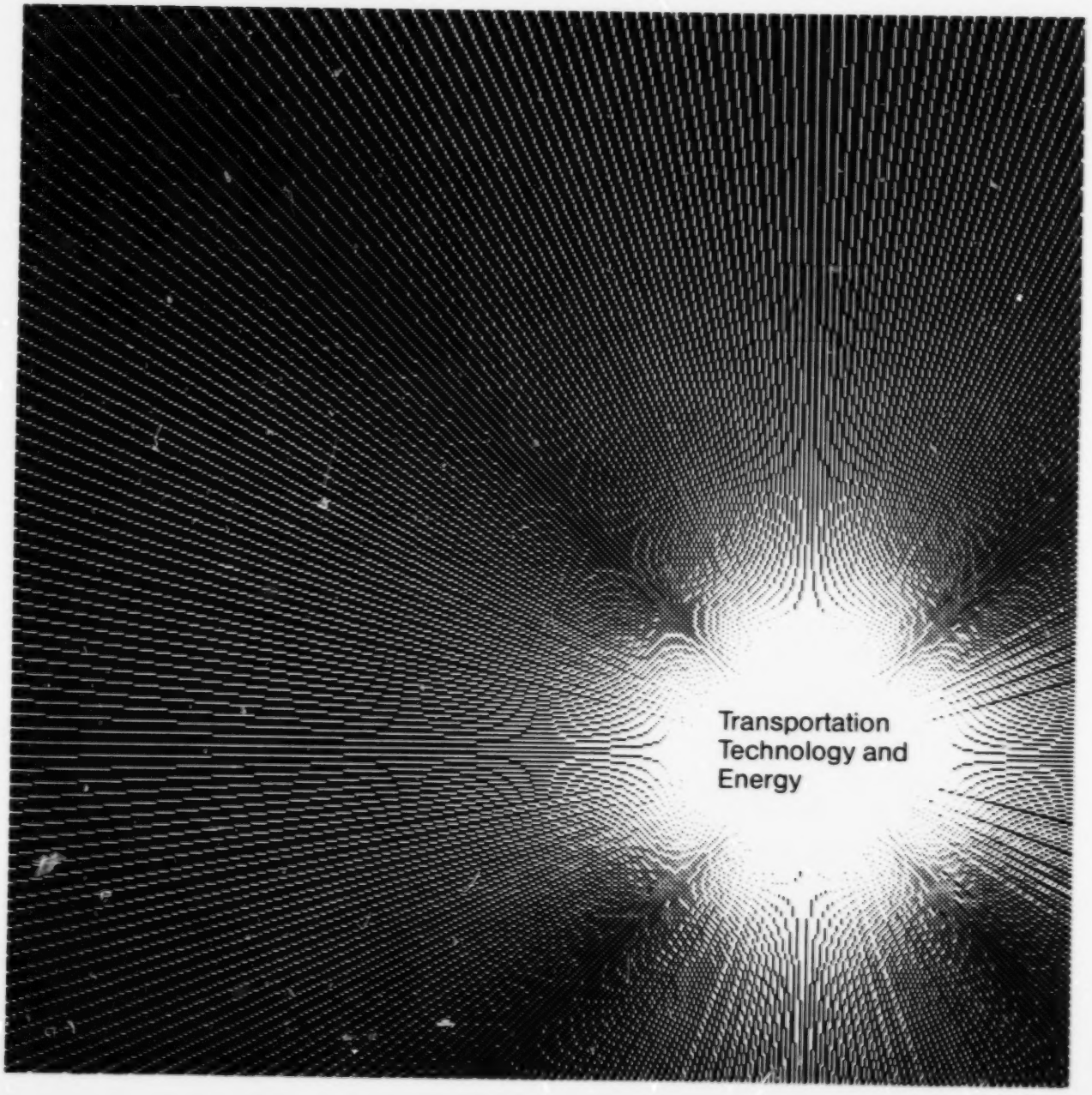

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Advanced Light Rapid Transit--
A Canadian Achievement

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ADVANCED LIGHT RAPID TRANSIT -- A CANADIAN ACHIEVEMENT

AppaRao, T.A.P.S.

1/ INTRODUCTION

The Advanced Light Rapid Transit (ALRT) System has been developed in Canada by the Urban Transportation Development Corporation (UTDC) to provide a cost-effective, flexible, environmentally acceptable and high-quality service solution for medium-capacity transit applications. ALRT systems have been in revenue service in Toronto since 1985, and Vancouver since 1986. Another system will commence revenue service in Detroit in August 1987.

Despite a few well-publicized teething problems, many of which were related to conventional elements of the projects such as civil works rather than the new technology, the ALRT system represents a significant achievement and offers a new transit solution to planners. The potential of this new technology is just now being explored and, like any other new technology, there are considerable opportunities for improvement. The ALRT offers the prospect of attractive and affordable capital and operating costs, which is very significant indeed for cities as they begin to plan for the transit needs of the next century.

The purpose of this paper is to provide an objective overview of the ALRT technology, the history of its development, descriptions of the three ALRT systems in use (or construction), and their performance to date. Finally, some comments are made on the future of this technology.

The author performed a review function for the Ontario Ministry of Transportation and Communications which funded the ALRT technology development and supplied much of the funding for the Scarborough RT project. This affords the author a perspective which is different from both UTDC, the technology developer, and the properties using the technology.

2/ ALRT SYSTEM DESCRIPTION

The ALRT system is designed for a capacity range of 10 000 to 30 000 pphpd (people per hour per direction). Thus, it fills the capacity gap between buses (5000 pphpd) and subways (40 000 to 50 000 pphpd). The capacity of this system makes it well suited to feeder and suburban lines in large cities and main lines in medium-sized cities.

The ALRT system uses small vehicles 12.5 m long and 2.5 m wide (Figure 1). The cars have seating for 30 to 40 passengers depending on interior configuration and a design capacity of 75 passengers. The maximum operating speed of the vehicle is

90 km/h. The small size of the vehicles allows for smaller guideways or tunnels and shorter platforms than for conventional transit (Figure 2). This, of course, means that the infrastructure cost, which represents the bulk of the capital cost of any rail transit system, is correspondingly smaller. Furthermore, the slender guideways and small platforms give more flexibility for the planner with regard to alignment selection as they can be integrated into cities more easily (Figure 3).

The ALRT system uses steerable trucks in which the axles are aligned radially as they traverse curves. Figure 4 illustrates the principle of the steerable truck. These trucks are designed to traverse curves down to 35 m radius without generating appreciable wear or noise, whereas conventional trucks perform inadequately on curves with a much larger radius. The short radius curving capability again gives the transit planners significant flexibility in selecting routes through busy city streets and reduces land acquisition requirements.

The trucks are designed to produce no more than 74 dBA at a distance of 15 m from the track centre lane when travelling at the top speed of 80 km/h (50 mph). This compares well with the best rail transit systems in North America. Low noise generation is essential in order that the system may be used in at- or above-grade application in cities; otherwise, the system will be forced underground with the attendant increase in cost.

For propulsion and braking, the ALRT system uses a linear induction motor (LIM) which is essentially a stretched-out version of the rotary motor as shown in Figure 5. The use of LIM enables the vehicle to negotiate much higher grades (up to 12%) than can be done when relying on wheel/rail adhesion. More importantly, LIM braking provides consistent and reliable braking distances under all weather conditions, which is a definite advantage, particularly for an automated system.

The ALRT system also features a health monitor which constantly checks the status of dozens of subsystems and reports malfunctions to a central control. It helps prevent serious problems from developing by catching them early.

Finally, the ALRT is a fully automated system. It uses the SELTRAC system developed by SEL Canada, which works on the so-called moving-block principle. In a moving-block system, each train is allowed to come as close as possible to the preceding train without compromising safety in any way. This method of operation allows much shorter headways (i.e., time interval between trains) than are possible with a conventional fixed-block system. The ALRT system is capable of headways down to 60 seconds. Short headways, of course, enable relatively large system capacities to be realized even though the trains are small.

The structure of the SELTRAC system is shown in Figure 6. The system has computer equipment operating at three levels -- management, operations, and activation.

At the management level, the System Management Centre performs automatic train supervision functions. It schedules trains and hours of service, triggers platform announcements, monitors train equipment, provides voice communications for emergencies, etc. None of these functions are safety related, but do provide convenience and flexibility in operating the transit system.

At the operations level, the Vehicle Control Centre (VCC) is responsible for safe train separation, routing and other train protection functions. The VCC has three mini-computers, at least two of which must agree on every command given. The VCC is in constant communications with each train it controls as well as the other VCCs. Among the functions of the VCC are setting speed limits for trains, establishing safe stopping distances and setting track switches.

The VCC communicates with the Vehicle on Board Control (VOBC) through track-side feeding devices and the inductive loop cable laid along the track.

Each train typically has at least two cars equipped with VOBC units. The VOBC is responsible for safe train operation within the limits imposed by the VCC. The VOBC has two microcomputers, both of which must agree on each command given. If there is disagreement, the VCC shuts down the VOBC in question and switches to another VOBC on the train. The VOBC serves many functions: it continually reports speed, direction and location; opens and closes doors, controls heating, lighting and ventilation; directs the propulsion system to accelerate and brake on command; and it relays data on train equipment performance.

3/ HISTORY OF THE ALRT TECHNOLOGY DEVELOPMENT

The Urban Transportation Development Corporation in Kingston commenced the LRT technology development in 1975 under funding support given by the Government of Ontario. A state-of-the-art review was conducted in 1975 followed by a system definition in 1975-76. The prototype design, fabrication and testing was done during 1976-80, when three test vehicles were built and tested. In 1980-81, the "production" design was completed and two pre-production vehicles were built and tested.

In 1981, UTDC signed a contract for the Vancouver system. This was followed in 1982 by two contracts, one for the supply of vehicles for the Scarborough system and the other for a turnkey people-mover system in Detroit. During these contracts, much further development and testing of the system took place. The

Scarborough system opened in March 1985 while the Vancouver system opened in January 1986. The Detroit people-mover system is scheduled to open in August 1987.

4/ SCARBOROUGH RT

The Scarborough RT System is a 7-km line in suburban Metro Toronto, extending from the Kennedy subway station to McCowan Avenue, just east of the Scarborough Town Centre. A decision was made in 1981 to use the ALRT technology for this line. It is a tribute to TTC, UTDC and its suppliers that this system, based on novel technology, and, in fact, incorporating some significant changes, progressed from a pre-production stage to a working revenue system in less than four years.

One distinquishing feature of the Scarborough system is that its trains have operators on board. The system can operate in three modes:

1/ Emergency Mode, in which there is no signal protection or control and the operator drives the train by line of sight;
2/ Cab Signalling Mode, in which the operator drives the train with the help of signal aspects displayed in the cab and with full train protection provided by the signal system;
3/ Automatic Train Operation, in which the driver closes the doors and starts the trains at stations but all other functions are performed by the signal system.

The current service in Scarborough consists of nine two-car trains during rush hour, six trains between peaks and four trains during off hours. The system has a fleet of 28 cars.

5/ VANCOUVER SKYTRAIN

The Vancouver system is a 21-km line extending from the Seabus station to New Westminster. It represents the first application of the ALRT technology as it was originally designed, i.e., driverless operation. In fact, the Vancouver system is the largest driverless transit system in the world. Even the maintenance yard is fully automated. It has a fleet of 114 vehicles.

Currently, service is provided between 5:20 a.m. and 1:15 a.m., with four-minute headways during rush hour.

One interesting feature of the Vancouver system is that it uses a self-service fare system. Roving transit attendants are used to perform many functions besides ticket checking. They provide public information, are trained to operate the vehicles in manual mode if it ever becomes necessary and can also attend to minor technical problems.

Another special feature of the system is the Platform Intrusion Emergency System (PIES) which detects intrusions on track at stations and automatically stops trains.

6/ DETROIT DOWNTOWN PEOPLE MOVER

This is a single track, 2.9 mile long downtown loop system. It has 12 stations and a fleet of 12 cars. Like the Vancouver system, this system will also be operated without drivers.

7/ OPERATIONAL EXPERIENCE

This section describes briefly the operational experience to date with the Scarborough and Vancouver systems.

7.1/ Scarborough RT

One of the main objectives of the Scarborough RT system was to encourage land development. In this regard, the system has been a phenomenal success. As shown in Figure 7, the office space near the Scarborough Town Centre more than tripled from 1982 to 1986. A future increase of over 50% is expected by 1990. The office employment is expected to more than double from a 1985 level by 8100 to 19 600 in 1990 [2]. Figure 8 shows an aerial view of the development near the Scarborough Town Centre.

When the decision was made in 1981 to build this system, a mature ridership of 3600 people per hour in peak direction (pphpd) was predicted. In two short years, the ridership has grown rapidly close to this level. The system has therefore been successful in meeting its ridership objectives.

In terms of determining the overall performance, the frequency and length of system delays represent good measures. After experiencing some teething problems, the system performance showed a dramatic improvement. By the fall of 1986, there were 6 to 13 delays per week for a total of 25 to 45 minutes. Not a bad performance for a system incorporating several new technologies.

One of the most publicized problems with the RT system is that of the wayside noise. But noise problems are often subjective, and in order to evaluate the ALRT technology with regard to noise, it is important to deal with objective measures. The vehicle specification calls for 74 dBA at 15 m from track centre line at a speed of 80 km/h. Recent measurements indicate that most vehicles either meet this or nearly meet it, i.e., within 3 dB. These noise levels have not satisfied all of the nearby residents, however, as they were used to living in an extremely quiet neighbourhood and hence perceive a significant change. However, it should be noted that the noise

level achieved compares very favourably with the best rail systems in North America.

While the wayside noise has nearly met the target levels, this has been achieved at the expense of considerable amount of wheel/rail maintenance. Wheel turning interval needs to be increased, and the need for rail grinding should be reduced. UTDC have conducted an extensive test program which has identified three promising improvements: a new wheel profile, a new steering mechanism and an electronic brake control system. The latter promises to reduce drastically the wheel flats, the major component of wheel wear in Scarborough. It is expected that the Scarborough wheel/rail wear performance will be improved to a satisfactory level by one or more of these improvements.

Another problem area with the Scarborough RT during the first winter was power rail icing. It causes power interruptions which in turn cause failure of propulsion control system. The original project plan called for installation of power rail heating, but this was later deleted to reduce costs. Now heaters have been installed on a segment of the track where they are considered necessary. This is expected to fully rectify the power rail icing problem.

A number of other teething problems occured during the first few months of service, but most of these have now been resolved.

One of the biggest problems and challenges faced by UTDC and SEL was in providing the driver interface in a car designed for driverless operation. This turned out to be a much bigger undertaking than had been estimated. A number of problems experienced on the Scarborough RT, especially during the first few months of operation, were associated with this driver interface.

It is to the credit of TTC, UTDC and SEL that this major development exercise has been successfully carried out in parallel with project delivery. Thanks to these efforts, a proven cab signalling option now exists for the ALRT.

7.2/ Vancouver SkyTrain

Vancouver SkyTrain has been a major success since opening on January 3, 1986.

The first year ridership on the system was 34 million passengers, or an average of 93 600 per day [4]. During Expo'86, the daily average was as high as 140 000. In 1987, the ridership has settled down to a level of 53 000 on week days and somewhat lower on weekends. This is a remarkable achievement for a brand new system based on a brand new technology.

The automatic train control (ATC) system has worked extremely reliably, in fact exceeding the reliability targets by a large margin [5]. The ATC system provides the operator with an enormous flexibility with regard to scheduling, which is simply not available to conventional systems.

It is generally feared that the average rider would be highly concerned about travelling in a driverless train. The Vancouver SkyTrain certainly shattered this myth. According to a survey, 91% find the SkyTrain to be safe and 96% find it reliable.

The vehicles have been performing very well, averaging 180 000 km per vehicle during the first 16 months. To date, they have travelled, on the average, over 10 000 km per service-affecting defect.

The system has proven to be extremely safe, having now carried over 40 million passengers without a single fatality or serious injury.

The barrier free, proof-of-payment fare system has proven to be highly successful, with a revenue loss of less than 1%. Use of this type of fare collection system resulted in a significant cost reduction of stations.

The Vancouver system uses SkyTrain Attendants to carry out a number of functions besides ticket checking. They provide passenger information and assistance. They also perform a general security function, and they are trained to drive the trains manually when required and they respond to emergencies. Even though the trains are driverless and the stations have no ticket agents, there certainly is no lack of human touch on the SkyTrain. This feature appears to have worked very well in providing good service while saving on operating costs.

Another interesting fact is that the entire Vancouver system has a total staff of only 318 of which 98 are responsible for operations. Clearly, such a lean work force is a direct result of automation.

Not everything was problem free, however. Rail transit systems are so complex and the service requirements are so stringent that it is not uncommon for even a new fleet of conventional rail cars acquired by an existing property to experience some problems. It is in this light that the problems experienced by SkyTrain should be viewed.

The steerable truck experienced hunting at high speeds (above 70 km/h) as well as lock-up, a condition in which the axles run in a crabbed position after traversing a curve. As indicated in Section 7.1, UTDC have undertaken an extensive test program to find solutions to wheel/rail problems. There is every

confidence that the new steering mechanism together with the new wheel profile will completely resolve the hunting and lock-up problems.

Another problem experienced in Vancouver was noise resulting mainly from corrugations on running rails. A major rail grinding program has been undertaken which has brought the noise down to a low enough level to satisfy both the riders and the neighbours [4].

8/ ECONOMICS OF THE ALRT

8.1/ Capital Costs

A good measure for capital productivity of a transit system is Capital Cost per Kilometre per Week Day Passenger (CCKWDP). Parkinson [6] compared CCKWDP for nine transit systems including two heavy rail and six LRT systems. As per this comparison the Vancouver system has a CCKWDP which is the lowest at $450, with the other systems ranging from $510 to $2510. When the 1987 weekday ridership of 53 000 is used, instead of the 1986 value of 90 000, this figure will go up to $764, but it still compares favourably with most of the other systems. It should also be noted that the SkyTrain provides faster service and much greater flexibility of operation when compared to most of the other systems. Thus, the ALRT has been shown to give high capital productivity while providing better service and flexibility than other competing technologies. Further improvements in capital productivity are likely with a second generation ALRT system which incorporates improvements based upon the lessons learned in Scarborough, Vancouver and Detroit.

8.2/ Operating Costs

For 1987-88, the operating cost per vehicle-kilometre for the SkyTrain is estimated at $2.08 [4]. In comparison, the 1984 operating and maintenance costs for four light rail systems [7] in the US ranged from US $1.86 to US $8.55 per vehicle-kilometre with an average value of US $5.66. When inflation and currency exchange are taken into account, it is clear that the SkyTrain compares very favourably with the best light rail system. In fact the operating cost of the SkyTrain is less than one third of the average for the four US light rail systems.

Since the SkyTrain is a brand new system using a brand new technology, it is not unreasonable to assume that the unit operating costs will decrease further as more experience is gained and the problems are resolved. Also, one can expect even smaller unit operating costs from future ALRT systems, which incorporate appropriate design improvements.

Thus, it is clear that the ALRT is an overwhelming success from the point of view of operating costs.

8.3/ Labour Productivity

The operating and maintenance (O&M) labour cost in 1986 as a percentage of the total O&M cost for the SkyTrain was 42%. The corresponding value for an average North American transit system was 75%. Clearly the use of the ALRT technology yields high labour productivity, as may be expected.

9/ CONCLUDING REMARKS

From the foregoing, it is concluded that the ALRT met its objective of providing a (capital and operating) cost effective, flexible, environmentally acceptable and high service quality transit solution for medium-capacity applications.

This remarkable Canadian success story has been tainted somewhat by several reports in the media about problems, many of which had little to do with the ALRT technology itself. Nevertheless, these stories left the readers with the impression that the technology was to blame for all the problems. The author has attempted to provide an objective assessment of the technology in this paper by discussing both the achievements and the problems.

Like any other brand new technology, the ALRT has much further room for improvement both in terms of performance and costs. A number of these improvements are suggested by the operating experience to date. A challenge to the manufacturer, transit properties and the funders is to work together to develop this technology towards its full potential. If we do this, we will have a transit technology for the 21st century, not only for Canada but also for the world. If we do not, we will be importing similar technology from abroad.

ACKNOWLEDGEMENT

In addition to the material listed under references, this paper has benefited greatly from discussions the author had with many people, too numerous to mention individually, at TTC, UTDC Ltd., UTDC Inc., and BCRTC.

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Figure 1/ Interior of an ALRT vehicle

Figure 2/ Relative sizes of guideways and tunnels, Conventional Metro vs ALRT

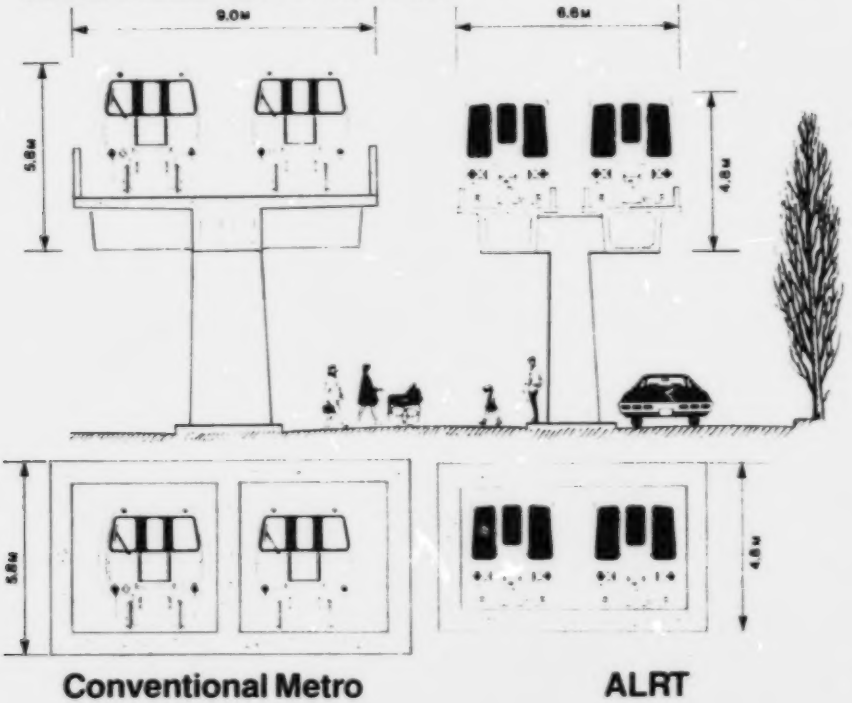

Figure 3/ The Vancouver SkyTrain travelling on a slender, attractive guideway

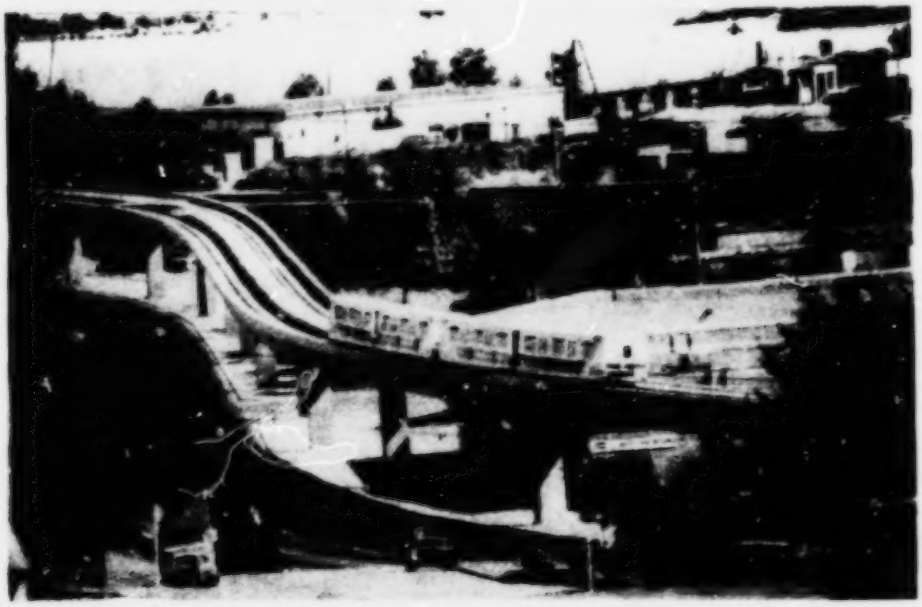

Figure 4/ Curve negotiation: steerable vs. conventional trucks

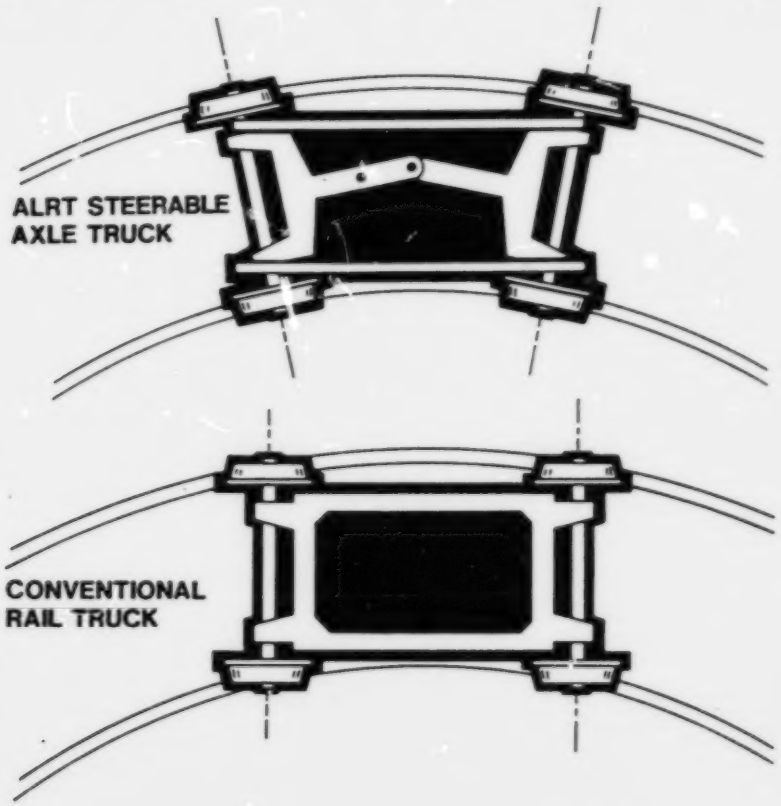

Figure 5/ Linear induction motor

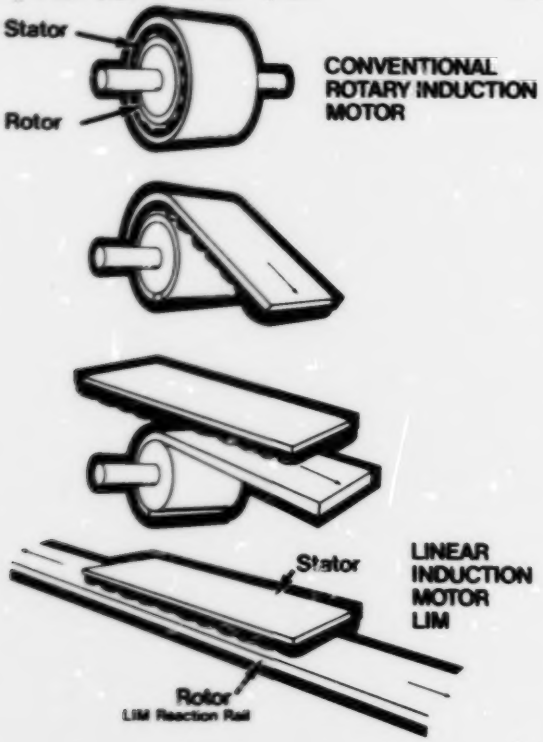

Figure 6/ SELTRAC automatic train control system configuration

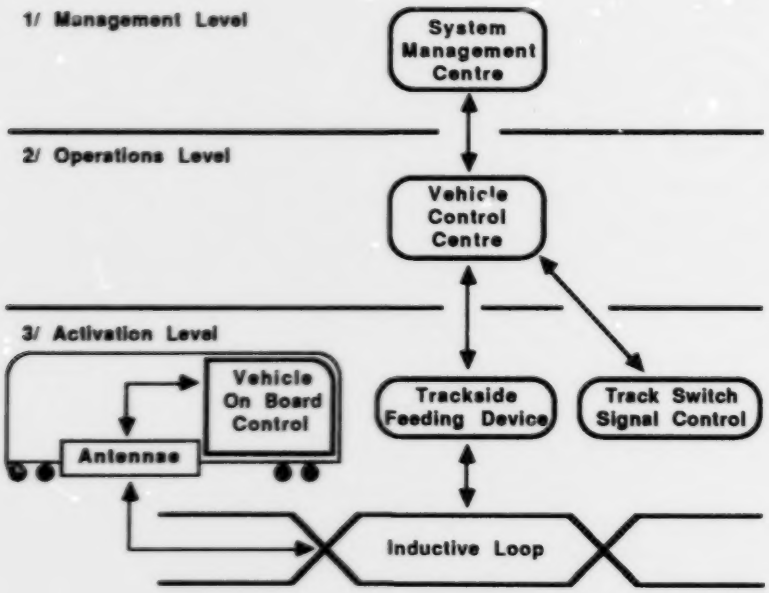

Figure 7/ Scarborough RT land development

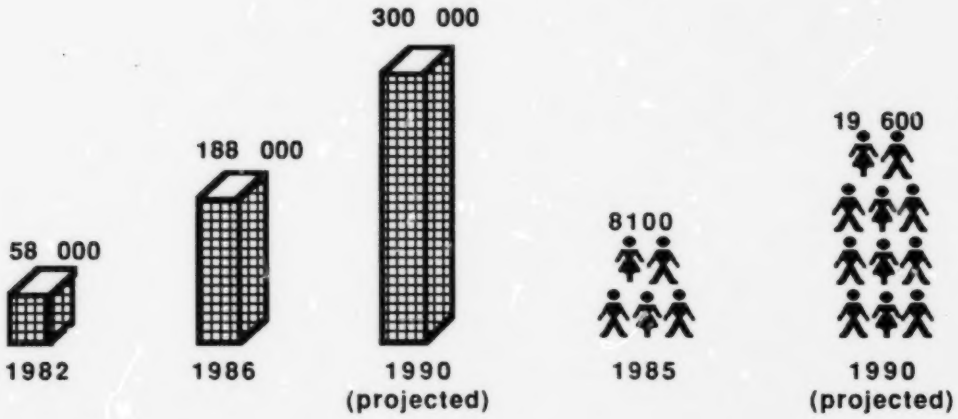

Figure 8/ Aerial view showing development near the Scarborough Town Centre